IPADS Case Study – Group 4

From waste to higher value-added products

Research Report

Xueting Ma, Hsiuming Liu, Xilin Zhang, Florence Lui
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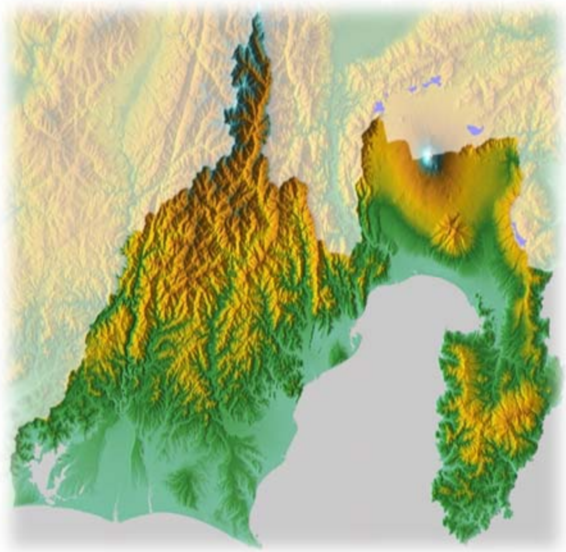
1. Introduction

1. Situation in Shizuoka

Shizuoka Prefecture (静岡県) is a prefecture of Japan located in the Chūbu region (中部地方) of Honshu. From east to west is 155km and from north to south is 118km. Since the middle of Shizuoka is narrow, if you look at the satellite view it just like a goldfish. There are a lot of mountains located at north & east side of Shizuoka prefecture, and world heritage---Fuji Mountain also is one of them. The climate of most area in Shizuoka prefecture is climatic type of the Pacific side of Japan.



Shizuoka Prefecture is famous as the producer of green tea and oranges, and also has thriving fishing industry.(Wikipedia contributors) Green tea growing area of Shizuoka Prefecture extends to 43% of the country.(静岡県, 2015b)

Growing area of green tea in Shizuoka prefecture

	Growing area	Around year	First tea-crop	Second tea-crop	Third tea-crop	Fourth tea-crop	Others
		Plucking area					
Japan							
2012	43,100	38,500	38,500	23,700	6,880	1,690	15,600
Shizuoka							
2008	19,700	18,500	18,500	12,200	815	231	6,680
2009	19,200	18,100	18,100	11,500	485	190	5,630
2010	19,000	17,500	17,500	10,500	408	204	6,420
2011	18,700	17,500	17,500	10,100	395	181	6,130
2012	18,500	17,300	17,300	8,770	386	190	6,120

Source: 農林水産省「作物統計」 ha

Therefore Shizuoka become the highest prefecture of green tea production volume, it accounts for 39% of Japan on weight basis.(農山漁村文化協会, 2008; 静岡県, 2015b)

Production volume of green tea in Shizuoka prefecture

	Around year	First tea-crop	Second tea-crop	Third tea-crop	Fourth tea-crop	Others
Japan						
2012	85,900	38,100	22,000	6,400	1,570	18,000
Shizuoka						
2008	40,100	17,100	12,500	780	232	9,480
2009	35,800	16,000	11,400	450	184	7,770
2010	33,400	14,200	9,610	402	198	9,020
2011	33,500	14,500	9,850	389	182	8,610
2012	33,400	16,100	8,290	380	183	8,460

Source: 農林水産省「作物統計」 ton

But if you focus on the economic activity in Shizuoka on value basis, you will find agriculture accounts for only one percent. The main economic activity in Shizuoka is the manufacturing industry. It accounts for 33%. And food & beverage production industry is most thriving in the manufacturing industry of Shizuoka.(静岡県, 2015a)

According to data, market of green tea beverages grows up around 5 times from 1994 to 2004, and it's still growing slowly.(全国清涼飲料工業会 & 日本炭酸飲料検査協会, 2015) In the making process of beverages, a large amount of waste is generated. Most of them still have a high value of reuse, like syrup, tea waste and coffee ground. But current situation is a beverage company must to pay high cost for waste disposal.

After years of effort, reuse rate of industrial food waste in Shizuoka prefecture is high now. But most waste disposal companies can only handle one to two kinds of food waste. But year-round supply of food waste is change violently by the season. Because of this, they need to very careful about the balance of input (food waste) and output (final product). And this led to many limited. For example, the final product must to demand throughout the year, and demand must be higher than the amount of food waste. It makes waste disposal company must to abandon some newer and better technologies and products.

On the other hand, Shizuoka Prefecture is also working hard on biomass utilization. To converted society from dependence of oil to sustainable, Shizuoka Prefecture formulates "Shizuoka Prefecture biomass comprehensive utilization master plan" in 2005. How to make effectively use the biomass from food waste becomes a big challenge.

On the basis of above, our team tries to design a system to reuse those food wastes more efficient.

2. Shizuoka visit

Japan's Food Recycling Law was enacted in 2001 and revised in 2007 in order to promote the reutilization of food resources. It encourages food-related businesses to reduce the generation of food waste during production in order to implement recycling methods and to promote heat recovery and weight reduction. The most successful implementation is represented by eco-towns and "recycling loops", recycling facilities working in symbiotic relationship between industrial and urban areas and improved recycling systems circulating resources respectively.

This time we have a chance to visit three companies in Shizuoka. In this visit, we listened to the chairman presented about these companies' recycle system and thoroughly understand the actual situation of the Shizuoka waste reuse.

2.1 Shizuoka Yuka Kogyo Corporation

2.1.1 Company profile

Shizuoka Yuka Kogyo Corporation set up from Showa 54, since then it is specialized in processing waste and waste oil. The company is located in Shizuoka, and collected six places sources of waste near the Shizuoka. Soybean residue is the main by-product of making soybean milk and tofu, and there is considerable interest in its recovery, recycling and upgrading. After the development of soybean residue recycle technology, they have been committed to use plant waste oil for diesel engine fuel and achieved great success. They made a great contribution to food waste recycling in Shizuoka with the establishment of the new plant and new type dryer for food waste recycling business and combined primary, secondary and tertiary industries into a sixth industry to generate new added values.[1]

2.1.2 Manufacturing process of livestock feed

Okara is the by-product of soy beverage and tofu production. Moist okara from soymilk production has about 80% moisture. It resulting from further centrifugation can have as little as 65% moisture. After drying of okara which will be used as animal feed or livestock producers (swine and dairy) in close proximity to soy beverage production facilities. Dried okara also can use as mushroom bed and fertilizer and this company make dried okara 6000t per year. Besides, recycling sludge with bacterium fertilizer's functions can also use as fertilizer.

2.1.3 Energy regeneration process

Okara and potato peels can use for bio-ethanol added gasoline (Bio-ethanol accounts of 3% of total amount of fuel) and waste oil can use for bio-diesel fuel individual or industrial.

Coffee grounds are also use to make solid fuel here. The pellet-shaped fuel generates a sufficiently high level of heat and has been successfully manufactured at a low cost that is half as much as producing a wooden pellet.

Table1 ：Qualities of coffee pellet fuel

	Numerical value
Size	D:6mm L:≤25mm
Bulk density	720kg/m³
Fineness	0.8%
Moisture content	8.9%
Ash	1.1%
High heat value	*23.4MJ/Kg*

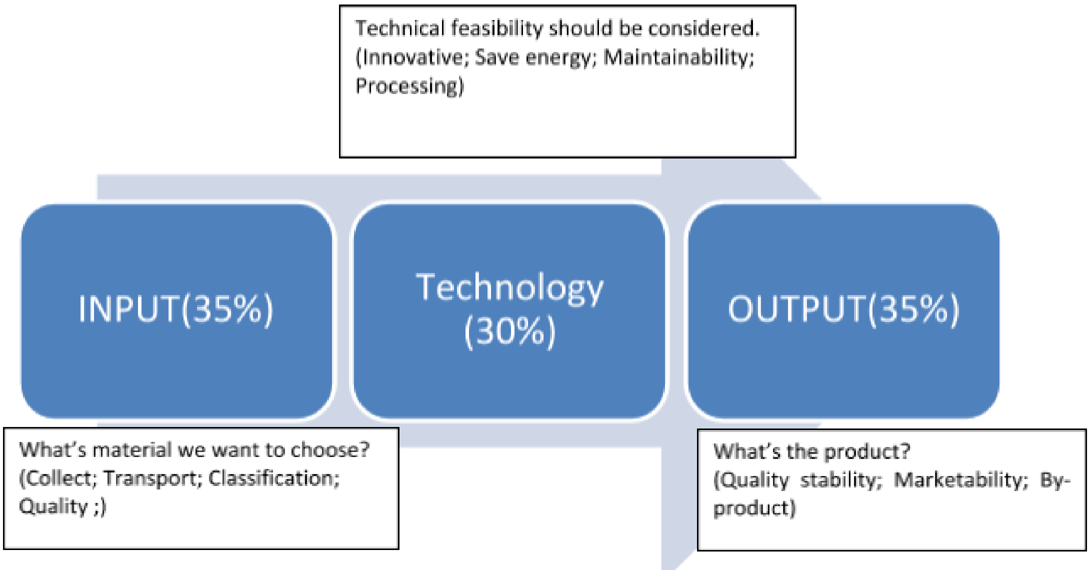
Table2 ：Cost per heat value

Type of fuel	Unit price （yen/MJ）
Gas	5.28
Kerosene	2.92
Heavy oil A	2.23
Wooden fuel	1.94
Coffeegrouns	1.07
Electricity	3.27

(source, Shizuoka Yuka Kogyo Corporation)

Shizuoka Yuka Kogyo has established a biomass boiler system. They collect 5 tons of coffee grounds a day, combine them with food waste like okara, and use them as fuel in place of heavy oil. This system can reduce CO_2 emissions by 580 tons a year. This system was approved as an emission reduction initiative for Japan’s carbon emission trading system in 2011.

2.1.4 Look ahead



Growing consumerism in Japan has resulted in a huge amount of waste generated daily, and exacerbated of the shortage of space available for landfills. Shizuoka Yuka Kogyo Corporation's chairman said, "The development of food waste recycling technology has become the urgent matter in Japan, but as a businessman, we have to think about economic benefits firstly. It is important to create IN/OUT social system."

In selecting raw materials, we must choose one or two products which have large amount of collection, even everyday can collect as much as possible. When the product is completed, we still need to consider a lot of problems. For example, how to deal with the by-product? If we use some material for making Mushroom bed, after processing we must deal with mushroom dishes. Actually, the output of materials first is used for agriculture application, the second is for fertilizer, the third is for energy regeneration, and new product development is the final choice.

In conclusion, accounts for only 30% of technology development in the whole process, the in/output balance and stability, and economic benefits point will account for 70%. Just make some new products which use domestic food wastes are not enough. While reducing the environmental burden, the new business models, infrastructures, technologies and policies in support of food waste recycling also had the direct objective of improving domestic production and stable food supply.

3.1 Yamanashi kanzume company

3.1.1 company profile

The company is mainly engaged in canned fruits and tuna processing and selling. Since 2009, in order to cut carbon dioxide emissions and reduce the cost, this company generates syrup waste to energy recycle process, which with great success in Shizuoka.[2]

3.1.2 recycle process

Generally, the discharge of syrup has high BOD numeric; in order to reduce that situation the company should spend more money to degradation. Then they just think about using syrup to energy utilization. After fermentation, the final mixing syrup can be used to generate power.

3.2 Shizuoka industrial research institute

3.2.1 company profile

This institute is mainly to accept the entrustment of Shizuoka enterprise specialized technical research and development as well as the research subject. And they engaged in recycling discarded food characteristics. The current researches already do pretreatment of food waste for methane fermentation and fertilizer use of methane fermentation digestive juice.[3]

3. Summary of visit

The importance of considering the economic implications of input and output of the recycling process, rather than just the possible value-added products that can be manufactured. So we want to find new ways to recycle products and aim for a zero-waste process by taking into account waste of waste. So we must focus on the potential to combine different wastes in a product, not only considering products made from one waste material.

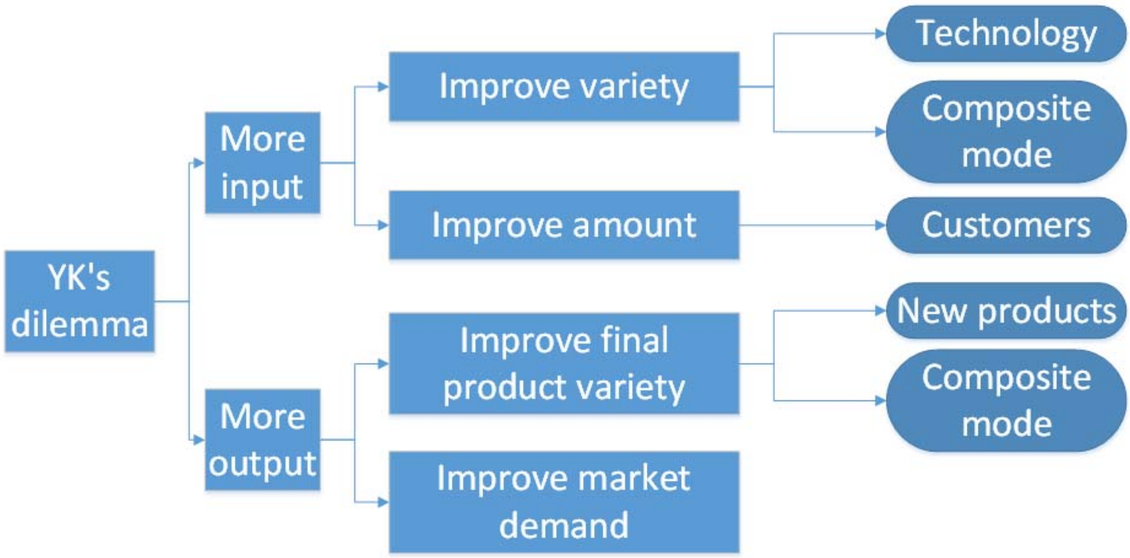
2. Objective

Before we visited Shizuoka prefecture, our objective was using those food wastes to make a new product which has higher economic value. But after we talk with food waste reuse company like YK, we realize all of our products have imbalance problem of input and output. The balance issue of

[3] http://www.iri.pref.shizuoka.jp/shizuoka/index.html

input and output make a big limitation to the final products of waste reusing. And we found to solve imbalance problem of input and output will be even more interesting than just develop a new product form waste. Therefor our group4's new objective is "Solve the limitation caused by imbalance between input and output. ".

To reach our objective, we build a logical tree to help us thinking how to solve this limitation.



First, we can commence form two part, input and output. To get more input we can improve variety and/or improve amount of food waste we gather. And also for the output, we can improve final product variety and/or improve market demand.

We sorted out the possible solutions have using the new technology, finding a new waste source, making a new product and developing a new composite mode. We have strong interest to every plan. But since we only have 2 months can work on this, we need to choose a most effetely and most feasible plan. To develop a new technology or a new product will take too long for us. And we don't have ability to find a new customer for wast reuse company. Therefore we decide to focus on make a composite mode to solve the limitation.

3. **Initial Model (Economic)**

The key take-aways from the professionals we met during the Shizuoka field trip include:

- The importance of considering the economic implications of input and output of the recycling processes, rather than just the possible value-added products that can be manufactured
- Seasonal fluctuations in input waste quantities pose an inventory management and production problem
- Finding new ways to recycle products and aiming for a zero-waste process by taking into account waste of waste
- The potential to combine different wastes in a product; rather than only considering products made from one waste material only
- The versatility of producing biofuel

Taking into consideration all the above-mentioned feedback, we believed that adopting the position of a waste recycling company, similar to Yuka Kogyo Corporation Inc. ("Yuka"), would allow us to investigate the effects of different allocations of input waste material on profit and the environment. The key food waste materials we considered in our research include tea, rice straw, rice husk, spent coffee grounds, okra, and citrus waste.

4. Research Plan

4.1 Introduction

We hypothesized that a recycle waste processing plant that produces both products that are manufactured from single recycle waste input products only ("Single Products") and combined recycle waste input products ("Combined Products") can achieve superior results to a plant that only manufactures Single Products, in terms of either profit or CO2 emissions. As such, we planned to examine the following scenarios for a recycle waste plant that processes okara, citrus, tea, rice husk, rice straw, and spent coffee ground waste.

4.2 Scenario Analysis

Optimal allocation of recycle waste inputs to generate outputs that produce Single Products or either result in the highest profit or lowest CO2 emissions.

We were going to examine the following three scenarios:

1. **Scenario 1 ("Control Scenario"):** Plant is to allocate input waste materials to Single Products only
2. **Scenario 2 ("Profit Scenario"):** Plant is to allocate input waste materials according to gross profit of output products (includes Single Products and Combined Products)
3. **Scenario 3 ("Environmental Scenario"):** Plant is to allocate input waste materials according to the lowest CO2 generated from the process of manufacturing output products (includes Single Products and Combined Products)

4.3 Method

As we were adopting the position of a waste recycling company that operates as a business in Shizuoka, we intended to analysing the effects of various allocation of input waste materials to produce the highest profit or lowest emissions. We intended to build an economic model on Microsoft Excel to examine our hypothesis over a 10 year period. In order to do so, we needed the following information:

1. Price and volume of input waste material
2. Price and volume of other chemicals and raw materials
3. Capital outlay (cost of machinery) and maintenance costs
4. Machine production capacity
5. Insurance costs
6. Utilities costs
7. Labor costs
8. Land rental costs
9. Tax (including environmental tax concessions)
10. Market price for output products
11. Environmental impact of process

4.4 Results

We intended to present the profit and environmental impact of all three scenarios over a ten year period in a graph (produced from Excel data) to support our hypothesis that a recycle waste processing plant that produces both products that are manufactured from Single Products and Combined Products can achieve superior results to a plant that only manufactures Single Products, in terms of either profit or CO2 emissions.

5. Initial Model (Economic) - Information Gathering Process

After building the initial structure of the model, we approached IRISP to gather information on market prices and input prices of key input and output products.

The following table is an example of the key categories of information we requested assistance in gathering:

Output product	Input product type
Animal feed	Combined
Biofuel	Combined
Fertilizer	Combined
Concrete	Combined
Glass	Combined
Mushroom bed	Combined
Binderless boards	Combined
Particle boards	Combined
Plastic	Combined
Activated carbon	Combined
Candle wick	Tea
Soymilk tofu	Okara
Tatami	Rice straw

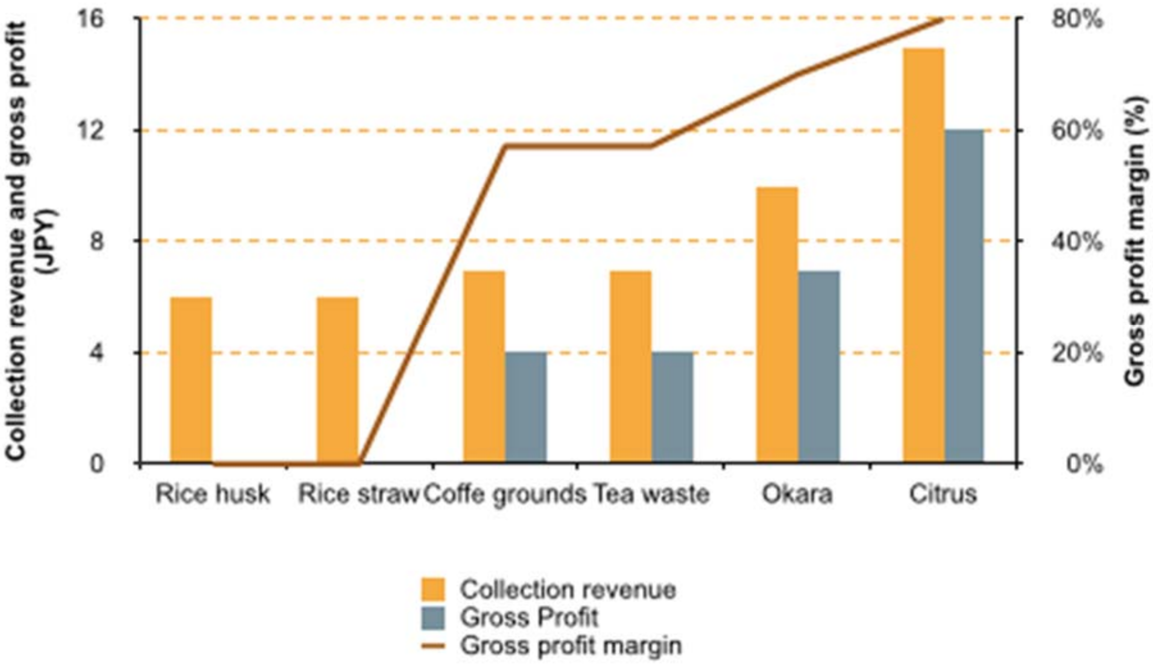
The key feedback we received from IRISP was that the information we requested are not public and very case dependent.

Key comments include:

- Prices of products are difficult to generalize as it is dependent on the relationship between the supplier and customer, the production scale, and target quality
- Since majority of the waste recycling companies in Shizuoka are private entities, they are not obliged to disclose price and profit margin information of their output products; many choose not to disclose such proprietary information

However, IRISP provided cost of collection (cost for the waste recycling company) and collection revenue (price that the waste recycling companies charge the food and beverage operators for collecting their waste) data.

Collection Revenue, Gross Profit, and Gross Profit Margin per kg of Waste Materials



Based on the information we received from IRISP, we could infer the following points about the Shizuoka waste recycling market:

5.1 Rice straw and rice husk

From this data we can see that rice straw and rice husk provides a gross profit margin of 0%. The reason IRISP provided for the high cost of collection of rice straw and rice husk for waste recycling companies is that rice straw and rice husk have low density, which requires larger sized trucks despite its low density - this has implications for fuel costs and labor costs. Also, since rice farms are located relatively further away, the transportation costs may be higher relative to the other forms of waste (e.g. food and beverage companies are located in Shizuoka so the transportation cost of collecting spent coffee grounds, okara, tea waste, and citrus are lower).

Further, rice husk and rice straw is a very valuable resource in other industries and rice farmers could potentially sell by-product rice straw and rice husk; decreasing the need to pay waste recycling companies to process the waste. As such, the 0% gross profit margin for collecting rice straw and rice husk may be a conservative assumption and it might actually be in the negative region.

We also observe that the waste recycling companies we visited in Shizuoka do not process rice straw and rice husk.

5.2 Okara and citrus

Through our research we found that okara and citrus were inputs to the products that ranked the highest in terms of value-add as they are used in cosmetics and functional foods.

Surprisingly, the profit margin for the collection component of the process already yielded very high profit margins. Interestingly, the waste recycling companies can sell the compounds that it extracts from okara and citrus back to the food companies - in that way it has already established demand for x% of its supply.

5.3 Coffee grounds and tea waste

Although profit margins and revenue were not as high as for citrus and okara, at 57%, the collection of spent coffee grounds and tea waste is still very profitable.

Since there is high volume of tea waste and spent coffee grounds in the Shizuoka region (where most of the large food and beverage conglomerates are located), they stand as very effective volume plays for waste recycling companies.

5.4 Summary

After analyzing the above information and observations, we decided to shift our focus to a simpler illustrative model with less reliance on exact price figures.

As Yuka expressed concern over seasonal changes on fluctuations in the quantity of input materials, and its effect on reliability of producing a minimum quantity of output product in a given period, we decided to focus on how Yuka can better manage its supply of input materials to meet demand for its output products instead.

We believe that analysing the key drivers of output, the relationship of seasonal differences between raw materials and their input, and how operating a plant with common products can better reduce the risks of waste recycling companies is more important.

Other conclusions include:

- Although interesting, especially given rice is a main produce of Japan, rice husk and rice straw should be at low priority for a waste recycling company in Shizuoka
- Okara and citrus should be given high priority
- Coffee and tea waste should be given medium priority - as it is more of a volume play
- Manufacturing more higher-value added products is beneficial for waste recycling companies (Yuka is already making investments in this area and is building an in-house engineering team. Further, the company has frequent communication with IRISP)

6. Revised Model Simulation (Seasonal input hedge)

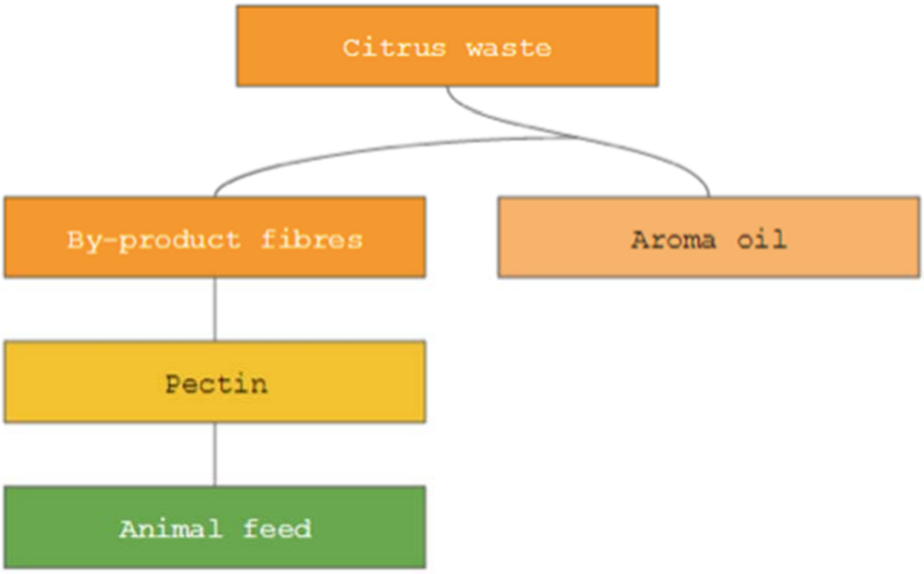
6.1 Research Plan

6.1.1 Introduction

Our revised model ("Revised Model") aims to investigate how combining waste materials with different seasonal cycles may act as a natural hedge for the uncertainty related to fluctuations in seasonal inputs.

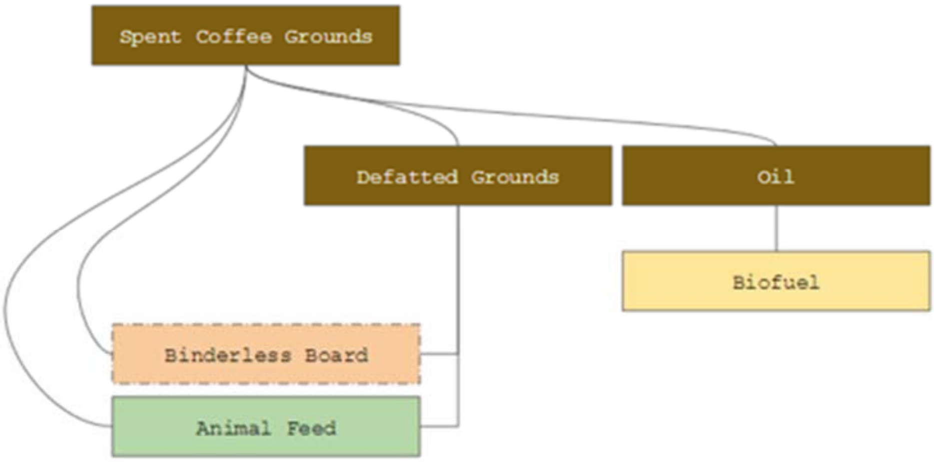
Revised model includes the key citrus and spent coffee grounds recycle products only as yield data for these products are publicly available. The below diagrams show zero waste recycles associated with citrus waste and spent coffee grounds respectively (see Appendix for further information on production processes). Also, as majority of citrus beverages are consumed in summer as a cold drink, we believe it has distinct seasonal cycles from coffee (whereas seasonal fluctuations in tea waste would have high correlation with coffee).

Diagram of a Zero-waste Citrus Cycle (focus on key products)



After aroma oil is extracted from citrus waste, pectin can be extracted from the resultant by-product and further converted into animal feed.

Diagram of a Zero-waste Spent Coffee Grounds Cycle (focus on key products)



After coffee oil has been extracted and converted to biofuel, binderless boards (theoretically, as binderless boards that meet national standards have yet to be produced from spent coffee grounds - see appendix for further details) and animal can be produced from the resultant defatted coffee grounds.

6.1.2 Scenario Analysis

Optimal allocation of recycle waste inputs to reduce fluctuations associated with seasonal cycles.

We will examine the following three scenarios:

1. **Scenario 1 (“Citrus-only Scenario”):** Plant collects and processes citrus waste only
2. **Scenario 2 (“Coffee-only Scenario”):** Plant collects and processes spent coffee ground waste only
3. **Scenario 3 (“Combined Scenario”):** Plant collects and processes spent coffee ground and citrus waste to produce both single input and combined input products. Dry pellets (or animal feed) are the only combined input products, whereas all the other products are standalone products

6.1.3 Method

Revised Model simulation to be built on Microsoft Excel to examine our hypothesis over a one year period with focus on seasonal changes. Note that the model simulation are for illustrative purposes only.

Our key assumptions are outlined in the following table:

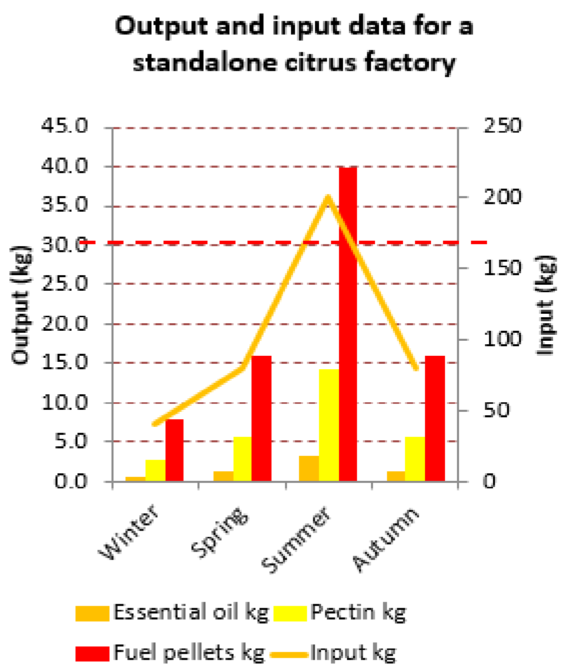
Annual input	800 kg
Coffee seasonality	Winter: 35% / Spring: 20% / Summer: 25% / Autumn: 20%
Coffee biodiesel yield	12.5%
Binderless boards yield	90%
Dry pellets yield	50%
Binderless board / dry pellets allocation rate	50%
Annual input	400 kg
Citrus seasonality	Winter: 10% / Spring: 20% / Summer: 50% / Autumn: 20%
Essential oil yield	1.6%
Pectin yield	7.1%
Dry pellets yield	21.8%

Source: Kondamudi N, Mohapatra SK, and Misra M (2008). Spent Coffee Grounds as a Versatile Source of Green Energy; Goodrich RM et al (2006). Major by-products of the Florida Citrus Processing Industry

6.1.4 Results

` The results for all three scenarios are presented as graphs compiled from output data generated from our Revised Model on Excel.

The results support our hypothesis that a Combined Scenario with multi-input allows waste

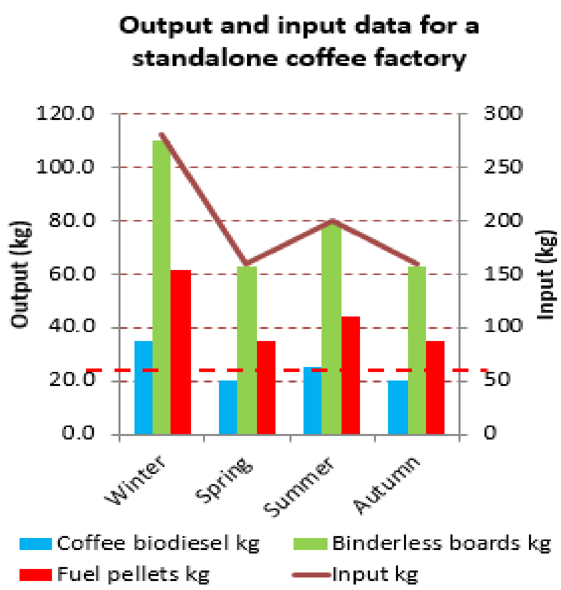


recycling plants to reduce risk of seasonality fluctuations and maintain volume of output products to ensure a secure supply to its customers.

Output and Input Data for a Standalone Citrus Factory

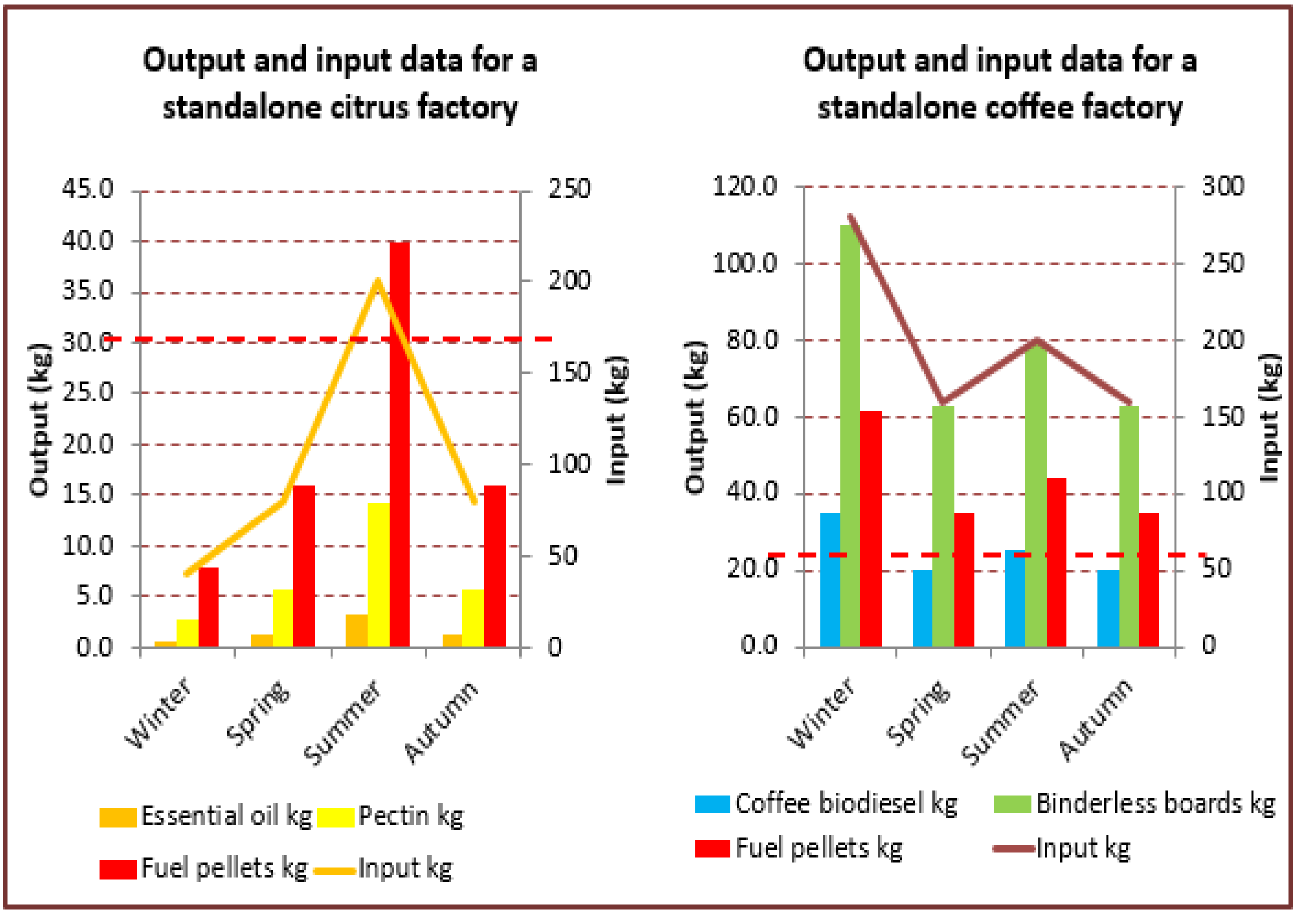
The red line shown in the above graph is a hypothetical minimum quantity of fuel pellets orders from customers who require consistent supply throughout the year (despite seasonal changes in input materials). For a standalone citrus plant, output may not be able to meet demand during seasons with low waste material collection.

Output and Input Data for a Standalone Coffee Factory



The red line shown in the above graph is a hypothetical minimum quantity of fuel pellets orders from customers who require consistent supply throughout the year (despite seasonal changes in input materials). For a standalone coffee plant where collection volume is much larger, the plant may not encounter the same issues as the citrus plant but will generate excess supply.

Combined Graph

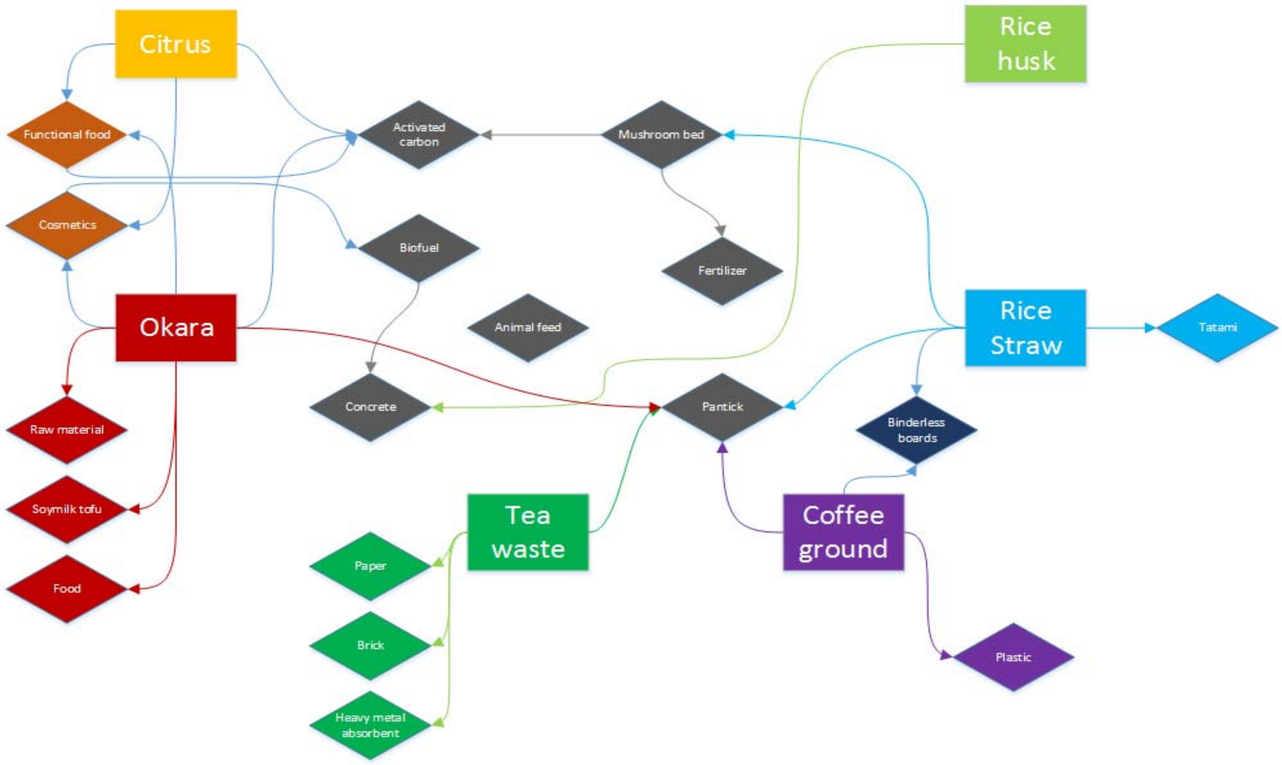


As the input cycles and volume of citrus and spent coffee ground waste complement each other, operating a combined plant reduces the risk associated with seasonality fluctuations and allows the plant to provide a stable output of products to its customers.

7. Simplified Model

As we discussed before, the gathering of the price of collecting those food waste is limited. The relationship between the collecting company and the food waste creator might have an influence on the collecting price as well as the market demand will also have an effect. Even the industry person does not have the idea about all the collecting price of all food waste. Therefore, our group cannot actually finish the model. Here we would like to provide a simplified model to just demonstrate the general structure.

Below is the demonstration of simplified model.



The component of figure might be changed such as the food waste can be replaced by different kinds of food wastes based on the actual situation. Although the structure looks really difficult to understand, it is a simply model.Demonstration of Simplified ModeTake Yuka Company as an example, the original materials will be okara, tea waste and coffee ground. At the beginning, these food wastes were used to produce animal feeds. We now try to collect different kinds of food wastes. Here, we add the variety of citrus waste, rice straws and rice husks. In this way, when one of the food wastes are in shortage, the company still can use other food wastes to manufacture their products. In addition, we are trying to create common final products. Through knowing the final products, we are able to help the company to avoid the risk of producing products with low market demand. If the previous product has low market demand, the company is able to manufacture other products so that they will not suffer from economic loss.

8. Conclusion

Theoretically, the limitation we discussed before can be solved with the model we propose. By improving the variety of input materials as well as the possibilities of manufacturing different final products, waste processing companies are able to get rid of the risk of suffering from economic waste. However, in our project, due to the difficulty of collecting data, we are not able to actual finish the model.

To complete this model, a standardized waste collecting price is required. The collecting price needs to be set and should not change based on the relationship between waste creator and waster processer. To understand the rise and fall of food waste price, a large quantity of data is required such as several years of the food waste price. What's more, the price market should be transparent so that every company can have an access to the information and decide the development plan.

Another suggestion to the waste companies is that they need to focus more on high value food waste. For example, citrus waste can be used to manufacture functional foods as well as cosmetic, which indicates citrus waste is a high-valued food wastes. Companies need to keep an eye on these wastes instead of rice straw and rice husk. Although the manufacture of recycling high-valued food waste might require high technology, the profit might be higher and the efficiency of recycling will be improved. Those easy-recycled food waste might be collected by more companies. If focusing more on high-valued waste, then the recycling rate might be improved.

9. Appendix: Recycling of Coffee Grounds, Rice Husks, Citrus, Okara and Tea Waste.

9.1 Spent Coffee Grounds

9.1.1 Introduction

Spent coffee grounds are a by-product of the coffee brewing process. The typical coffee production process includes the roasting of green coffee beans, the grinding of roasted coffee beans, and running water through the coffee grounds to produce coffee.

Food and beverage companies that produce canned and instant coffee ("Ready-to-drink Coffee") in bulk utilize mass brewing methods. The resultant coffee brew is then either spray dried, freeze dried, or canned. As expected, industrial coffee brewing produces significant amounts of waste at the factory site. In Japan, the Ready-to-drink Coffee Market accounts for c. 40% of total roasted coffee[4]. Industrial coffee factories are predominantly based in Shizuoka, Japan. The market is dominated by a handful of large companies. As production sites are concentrated in the same area and produce large volumes of wastes, collection is relatively efficient and easy to implement.

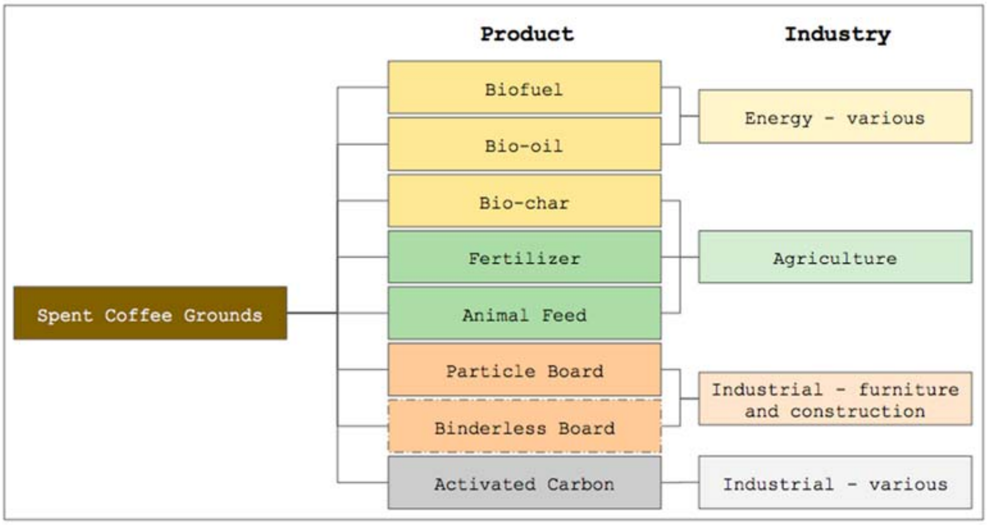
Cafes and restaurants together account for 29% of the roasted coffee market in Japan[4]. The market is highly fragmented and geographically dispersed. Collection from such retail points are harder to implement and enjoy less economies of scale than industrial collection.

The remaining 31% of the roast coffee is brewed for home consumption. Collection of spent coffee grounds from individual homes is impractical.

9.1.2 Spent Coffee Grounds - Waste or Resource?

Although it is regarded as a waste by food and beverage corporations, cafes, and households, spent coffee grounds contain many attractive qualities and valuable compounds that allow it to be converted into a range of useful products.

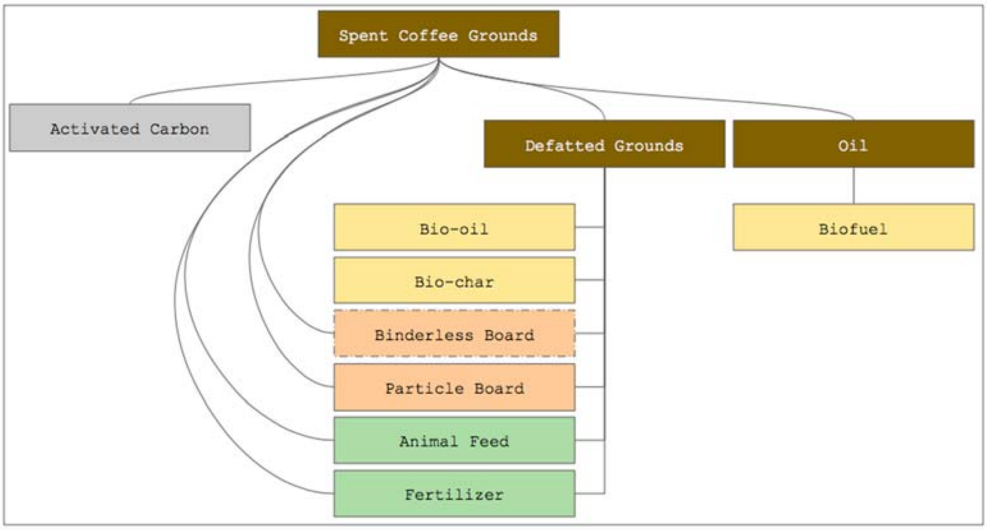
Coffee Diagram 1: Diagram illustrating different products that are derived from spent coffee grounds



* Note that binderless boards manufactured from spent coffee grounds has not been officially reported - though Tokyo University's Plant Material Science laboratory is undertaking experiments to tests the feasibility of producing binderless boards from spent coffee grounds (due to high lipid content, fats may need to be first removed by the extraction process)

Out of the key products that are examined, main end users include the energy, agriculture, furniture, construction, and various industrial industries.

Coffee Diagram 2: Diagram illustrating how different products manufactured from spent coffee grounds relate to one another



* Note that binderless boards manufactured from spent coffee grounds has not been officially reported - though Tokyo University's Plant Material Science laboratory is undertaking experiments to tests the feasibility of producing binderless boards from spent coffee grounds (due to high lipid content, fats may need to be first removed by the extraction process)

As illustrated in Coffee Diagram 2, no waste is produced from the manufacture of value-added products from spent coffee grounds if multiple products are considered in the chain.

Production of activated carbon leaves no waste

Production of coffee bio-diesel is achieved by first extraction coffee oil from spent coffee grounds and then further trans-esterifying the coffee oil. This process produces defatted spent coffee grounds as a by-product

Defatted spent coffee grounds can be made into a number of products including:

Bio-oil and bio-char (slow pyrolysis process)

Binderless boards and particleboards (hot press process)

Animal feed and fertilizer

Although binderless boards, particleboards, animal feed, and fertilizers can be made directly from spent coffee grounds, it is more efficient to manufacture these products after coffee oil extraction as biodiesel can also be produced, thereby further enhancing waste recovery (it is also more environmentally friendly when alternatives are considered - i.e. more fossil fuels will need to be combusted if it cannot be replaced by biodiesel) Superior particleboards and binderless boards can be produced when lipids are first removed from the spent coffee grounds as lipids correlatives negatively with board quality

The following sections further discuss the key value added products that can be made from spent coffee grounds in detail.

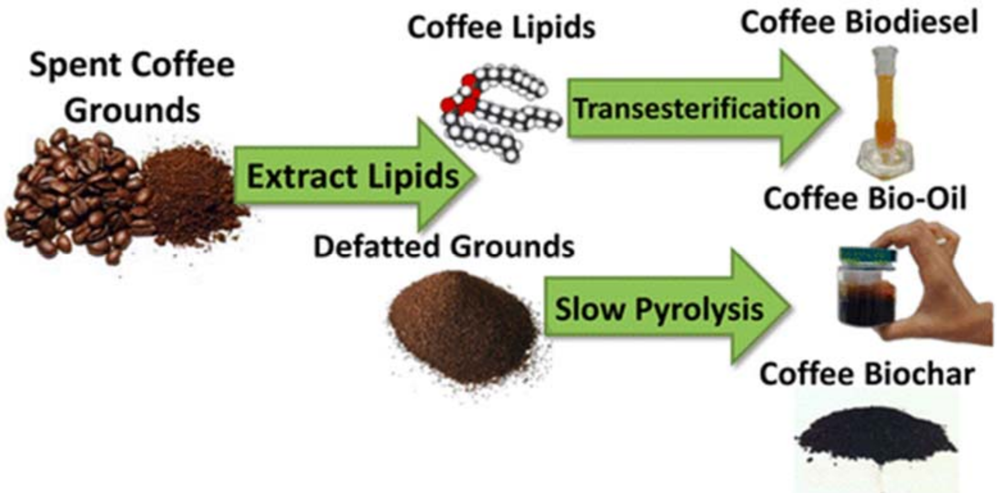
Coffee biodiesel [5]

Kondamudi N, Mohapatra SK, and Misra M outline the process used to convert spent coffee grounds into biodiesel in "Spent Coffee Grounds as a Versatile Source of Green Energy" - the following is the abstract of the paper:

The production of energy from renewable and waste materials is an attractive alternative to the conventional agricultural feed stocks such as corn and soybean. This paper describes an approach to extract oil from spent coffee grounds and to further transesterify the processed oil to convert it into biodiesel. This process yields 10−15% oil depending on the coffee species (Arabica or Robusta). The biodiesel derived from the coffee grounds (100% conversion of oil to biodiesel) was found to be stable for more than 1 month under ambient conditions. It is projected that 340 million gallons of biodiesel can be produced from the waste coffee grounds around the world. The coffee grounds after oil extraction are ideal materials for garden fertilizer, feedstock for ethanol, and as fuel pellets.

Coffee bio-oil and biochar [6]

Vardon DR, Moser BR, et al. outline the process used to convert spent coffee grounds into bio-oil and bio-char in "Complete Utilization of Spent Coffee Grounds To Produce Biodiesel, Bio-Oil, and Biochar" - the following is the abstract of the paper:



This study presents the complete utilization of spent coffee grounds to produce biodiesel, bio-oil, and biochar. Lipids extracted from spent grounds were converted to biodiesel. The neat biodiesel and blended (B5 and B20) fuel properties were evaluated against ASTM and EN standards. Although neat biodiesel displayed high viscosity, moisture, sulfur, and poor oxidative stability, B5 and B20 met ASTM blend specifications. Slow pyrolysis of defatted coffee grounds was performed to generate bio-oil and biochar as valuable co-products. The effect of feedstock defatting was assessed through bio-oil analyses including elemental and functional group composition, compound identification, and molecular weight and boiling point distributions. Feedstock defatting reduced pyrolysis bio-oil yields, energy density, and aliphatic functionality, while increasing the number of low-boiling oxygenates. The high bio-oil heteroatom content will likely require upgrading. Additionally, biochar derived from spent and defatted grounds were analyzed for their physicochemical properties. Both biochars displayed similar surface area and elemental constituents. Application of biochar with fertilizer enhanced sorghum–sudangrass yields over 2-fold, indicating the potential of biochar as a soil amendment.

Fertilizer and animal feed [7]

Menicon Co., Ltd ("Menicon"), a Japanese contact lens manufacturer, is teaming with Starbucks Coffee Japan, Ltd ("Starbucks") to convert spent coffee grounds collected from Starbucks' outlets to cattle feed or compost fertilizer.

Only broad stages of the process are available as the details of the process are not publicly available. The following outlines the various steps involved in the production of cattle feed or compost fertilizer from spent coffee grounds:

1. Waste coffee bean cakes are collected from Starbucks outlets in trucks which are already delivering chilled products to the Japanese coffeehouses - minimising storage and transport costs as well as carbon emissions
2. The waste coffee bean cakes are dehydrated
3. The residual dry spent coffee grounds are then processed using a lactic acid fermentation technique
4. The substance is then ready to be fed to cattle or be used as compost fertiliser

Particleboard[8]

Rachtanapun P, Sattayarak T, et al. outline the process used to convert spent coffee grounds into particleboards in "Correlation of density and properties of particleboard from coffee waste with urea–formaldehyde and polymeric methylene diphenyl diisocyanates" - the following is the abstract of the paper:

"The effect of urea–formaldehyde adhesive and polymeric methylene diphenyl diisocyanates adhesive on the manufacture of particleboard using coffee waste as a raw material was investigated. The coffee waste was blended with the urea–formaldehyde or polymeric methylene diphenyl diisocyanates, then hot-pressed at 140°C at two pressure levels. The particleboards were tested to certify their density, moisture content, thickness swelling, water absorption, bending strength and modulus of elasticity. The density, moisture content and bending strength of the sample increased, but thickness swelling and water absorption decreased with increasing quantity of the urea–formaldehyde and polymeric methylene diphenyl diisocyanates. The particleboard with urea–formaldehyde and polymeric methylene diphenyl diisocyanates at the same quantity, the density, moisture content, thickness swelling, water absorption, bending strength and modulus of elasticity of polymeric methylene diphenyl diisocyanates were better than urea–formaldehyde adhesive. At the same adhesive content, the urea–formaldehyde adhesive samples above 18% urea–formaldehyde content and all of the samples with PMDI adhesive met the Thai industrial standards."

Binderless Boards[9]

Binderless boards can potentially be manufactured from spent coffee grounds.

Similar to the manufacture of binderless boards from other fibrous by-products, the method would be as follows:

<u>Introduction</u>

Binder-less boards are types of particleboards that do not use synthetic adhesives (such as formaldehyde). The lignin, cellulose, and hemicellulose that is naturally found in the structure of the plant-based raw material is used for internal bonding.

In recent years, researchers have manufactured binder-less boards from by-products and waste products such as softwood from demolition sites, bamboo, coconut husks, rice husks, kenaf, and palm fruit husks.

Materials

Powdered wood, wood chips and husks of seeds are the most suitable for the production of binderless boards though binderless boards can potentially be made from spent coffee grounds. Due to high lipid content in spent coffee grounds, it may need to first go through an extraction process to form defatted grounds. The oil that is extracted as a by-product of this process can be used to manufacture bio-diesel[10].

Manufacturing process

After analysing the properties of the material, binder-less boards are manufactured under the following conditions:

A. Pressing temperature: to be determined ("tbd")
B. Pressing time: tbd
C. Pressing pressure: tbd
D. Board dimension: tbd
E. Powder:chip ratio: tbd
F. Moisture content: tbd (less than 20%)
G. Target board density: tbd

Testing

Binder-less boards are cut into test specimens after being conditioned at 20C and 65% relative humidity. The mechanical properties (bending, strength, internal bonding strength, thickness swelling, and water absorption) are tested against the Japan Industrial Standard for Fibreboard ("JIS A 5905 - 1998") and Particleboard ("JIS A5908 - 1998").
The binder-less boards' internal self binding mechanism is examined by chemical analysis and electron microscope scanning.

Results

Binder-less boards typically undergo the following tests:

- Modulus of rupture ("MOR")
- Modulus of elasticity ("MOE")
- Internal bonding ("IB")
- Thickness swelling ("TS")
- Water absorption ("WA")

The results are then compared to JIS A 5908-1998 and JIS A 5905-1998, though we can also test the binder-less boards against the standards of other countries.

Activated carbon[11]

Kante K, Nieto-Delgado C, et al. outline the process used to convert spent coffee grounds into activated carbon in "Spent coffee-based activated carbon: Specific surface features and their importance for H2S separation process" - the following is the abstract of the paper:

"Activated carbons were prepared from spent ground coffee. Zinc chloride was used as an activation agent. The obtained materials were used as a media for separation of hydrogen sulfide from air at ambient conditions. The materials were characterized using adsorption of nitrogen, elemental analysis, SEM, FTIR, and thermal analysis. Surface features of the carbons depend on the amount of an activation agent used. Even though the residual inorganic matter takes part in the H2S retention via salt formation, the porous surface of carbons governs the separation process. The chemical activation method chosen resulted in formation of large volume of pores with sizes between 10 and 30 Å, optimal for water and hydrogen sulfide adsorption. Even though the activation process can be optimized/changed, the presence of nitrogen in the precursor (caffeine) is a significant asset of that specific organic waste. Nitrogen functional groups play a catalytic role in hydrogen sulfide oxidation."

9.2 OKARA

9.2.1 Summary

Okara contains protein and fiber which have value and which can theoretically be used in food products that meet market demands and opportunities. Okara, however, must be processed quickly in order to maintain its integrity. This processing can be expensive and as a result, economic feasibility typically discourages the use of okara in human food. If these barriers can be overcome there may be an opportunity for companies to benefit and the soy industry may be able to realize lost potential.

It is a white by-product, resembling wet sawdust. Okara is high in fiber and protein. It is traditionally used as a food ingredient in Japanese soups, salads and vegetable dishes. It is often said to resemble coconut in its texture and form. In general, 250 kg of okara is produced for every 1,000 liters of soy beverage.

In Shizuoka, okara has already used for animal feed, fertilizer, bio-fuel, cat-litter, mushroom bed, and also for functional food.

Through our research we found that okara were input to the products that ranked the highest in terms of value-add-being used in cosmetics and functional foods. Surprisingly, the profit margin for the collection component of the process already yielded very high profit margins. Interestingly, the waste recycling companies can sell the compounds that it extracts from okara back to the food companies.[12]

9.2.2 Uses of Okara

a. Fertilizer

The leftovers from tofu manufacturing would be depleted of proteins and most other minerals. However, that isn't the case. In a study about the various uses of okara published by the Journal of Agricultural and Food Chemistry, Characteristics and Use of okara, the Soybean Residue from Soy Milk Production, the okara was found to be high in crude fibers but also contains 25% protein and other minerals as described in the article. The one thing missing from the article is okara's potential as fertilizer.

Okara would be useful as a fertilizer in the same way that leaf mold compost is a good soil amendment. In Japan, 25% of okara are used for fertilizer, all organic rich soil amendments depend on healthy soil microbial activity to break down the carbon. That process takes time and can initially cause a reduction in available nutrients to plants as the soil microbes sequester those nutrients. For that reason it is usually best to apply amendments like okara a few weeks to months before it is time to plant. That time period allows microbial action to take organic forms of nitrogen and phosphorous and make those nutrients available to the plant in an inorganic or mineralized form.

In the case of nitrogen, microbial activity will eventually cause slow denitrification while excess water will leach some nitrogen out of the root zone. Therefore, more nitrogen needs to add depending on the rate of loss. That can be achieved by growing green manures such as legumes (beans and peas) that have a symbiosis with bacteria that actually fix nitrogen into the soil from the atmosphere. When those crops are turned into the soil, the process of mineralization and denitrification starts all over again. In lieu of the green manures people just add compost or other plant-based amendments such as leaf mold compost, alfalfa or okara. These plant-based amendments will also add other nutrients like phosphorous that will not be lost to the atmosphere but have their own specific cycles in the soil/plant environment. The best gardens are ones that develop good fertility over time such that new additions of compost and other amendments replace the elements lost through harvest.[13]

b. Animal feed

Most okara is used as animal feed for livestock producers (swine and dairy) in close proximity to soy beverage production facilities.

Okara used in this manner:

• provides excellent and abundant nutrients for livestock production.
• has demand among local livestock producers
• relies on local use to reduce or minimize transport costs.
• eliminates cost of treating, or handling in other forms.[14]

c. Pet food

Okara can be used in pet foods as it contains high levels of extenders and protein. In this use, it must be dried completely and pelletized in order to allow for easy handing and possible reformulations into pet foods.

d. Bio-fuel

Okara mixed with potato skin after glycation ferment processing that can use for bio-ethanol and now Shizuoka has successfully adopting this technology.

e. Cosmetics

Mix okara and 50% ethanol in 1:4 and centrifugal 30 minutes under 30 degrees, then take the supernatant to make freeze-dry powder. This powder will dissolve in 50% glycerol to produce astringent which has certain effect of skin care.[15]

f. Mushroom bed

At present, some research has been use okara after lactic acid fermentation as a mushroom bed, which can provide better nutrition source. The combination with okara recycling and lactic acid fermentation that can reduce the mushroom cultivation time, increase yield and also can cut cost.[16]

g. Extender in meat product

The smaller particle sizes of okara increased the CL of pork meat gels have been showed in study. With the reduction of particle sizes of okara, the L* values of pork meat gels increased significantly. The reduction of the particle size of okara could decrease the textural properties, such as firmness and chewiness. When okara of the larger particle sizes was added into pork, its G′ and G″ were increased.[17] However, the sensory evaluation showed that pork meatballs with the smaller particle size okara were preferred by the panelists. Thus, there was a potential to apply the okara to improve the qualities of pork products.

h. Food

9.2.3 Barriers to the use of okara in food

Okara begins to degrade as soon as it is produced. Even refrigerated okara spoils in less than 2 days. Thus, okara must be used or processed at the site of production in order to be feasibly utilized in food production.

Drying okara is one method of salvaging product for future uses in food. This process, however, requires specialized equipment and is energy intensive. The resultant costs can be extremely high relative to the value of the product. This is the major factor limiting the commercial use of okara worldwide.

Freezing is an alternative method for handling okara, especially when a higher moisture content in the food formulation is desirable. This process requires infrastructure, a great deal of energy, and continuity along the entire transportation chain. Thus, the economic feasibility of handling and using frozen, wet okara, especially in large quantities is limited.

In some cases where the feasibility of sourcing okara for food uses is feasible, shared arrangements for the drying and or transportation may be an option. Regardless, trust and sharing of mutual goals will be important for any company considering long term use of okara.[18]

9.2.4 Options for primary processing of okara for use in food

9.2.4.1 Freezing

This method involves freezing the okara immediately after it is produced for use at another time. It is highly recommended that freezing occurs near the facility where okara is produced with actual utilization occurring elsewhere. To manage okara in this fashion requires:

- Large scale equipment to freeze okara quickly, and thoroughly;
- Freezer storage space to store frozen okara;
- Transportation systems to move frozen okara to food facilities;
- Systems to handle and utilize frozen, high moisture product;
- Detailed costing transportation costs, energy requirements, and storage to ensure feasibility.

9.2.4.2 Drying

This method involves drying okara so that is can be used in formulations with less moisture and without the need for freezing. As in other food processing applications, drying is a high energy process that can be expensive and that requires advanced technology. Reducing moisture requires careful consideration of economic factors and end product integrity. There are different options for drying high moisture product, although none are currently being used on commercial scale for okara in Canada.

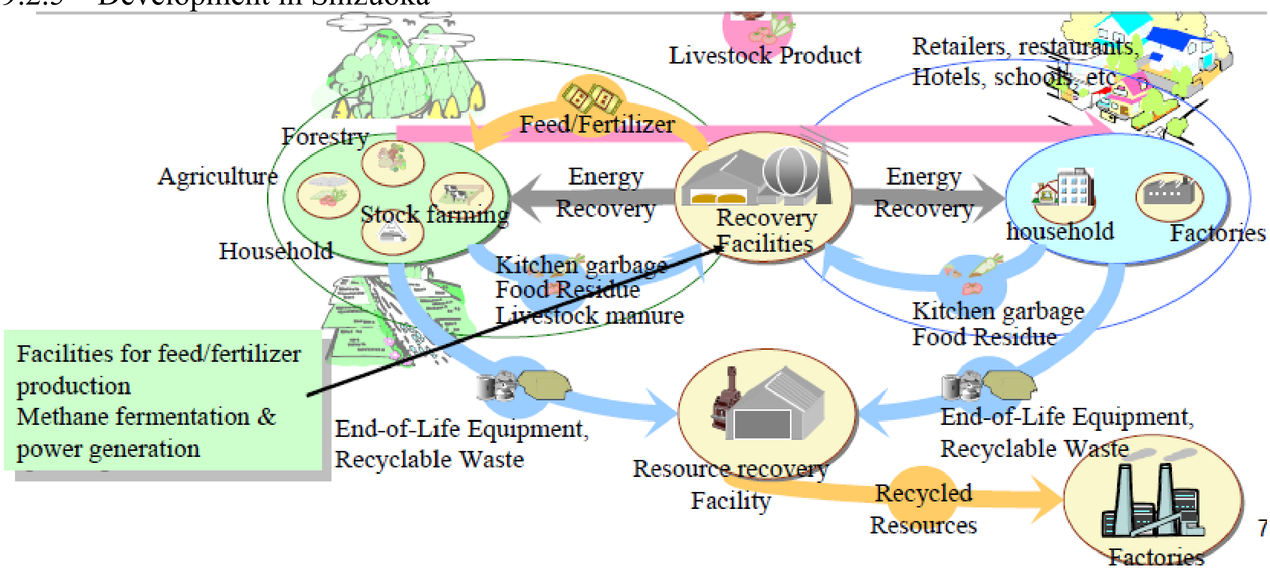
a. Double Drum (Roller) Drying
b. Cascading Rotary Drying
c. Spin-Flash Pneumatic Drying

9.2.4.3 Dried okara co-product considerations

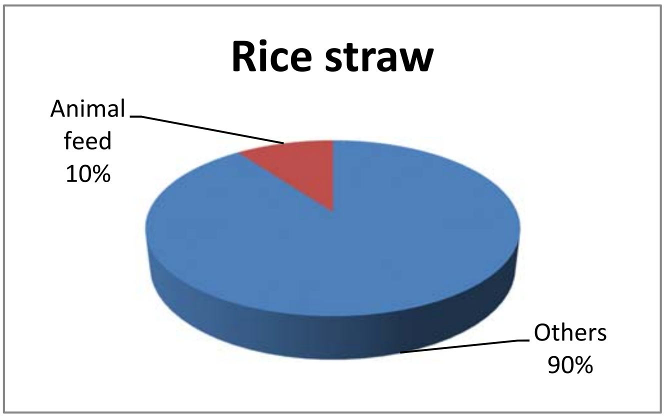
If okara production can be feasibly undertaken, consideration must be given to the production and handling of co-products. Given that primary processing mainly involves the removal of water from raw okara, water is the main by-product. For environmental and health reasons, this water must be handled appropriately.

If water can be free of micro-organisms and contaminants, it may be suitable for release into the environment by spreading on agricultural lands or re-introducing it into water systems (septic, municipal drains etc.). Spreading on land will likely require government permits and/or land use agreements with land owners. Release into water systems will require ongoing testing and approvals from appropriate government ministries and departments. If the effluent water is not suitable for disposal, it may need to be handled and treated as a wastewater product, similar to sewage. The degree and details of this co-product handling will depend greatly on the location of the primary processing the facility, the volumes being considered, and the composition of the water co-product.

9.2.5 Development in Shizuoka



9.3 Rice Straw



Rice Straw is an agricultural by-product, the dry stalks of cereal plants, after the grain and chaff have been removed. It has many uses, including fuel, livestock bedding and fodder, thatching and basket-making. Since Japanese staple food is rice, Japan produce 85.4 thousand tons rice straw per years. But most of them didn't reuse as well as we expected. Even Japanese cattle farm need large amount of feed, but only 10.1% of rice straw were used as animal feed. And other 89.9% didn't reuse effetely. According to the Japanese government's report, most of 89.9% were burned in farmland. It's not only wasting resources but also causing environmental pollution. For these reasons, we try to find out some other ways to reuse rice straw more effectively.

According to the references, rice straw can use as animal feed[21], medium[22], fertilizer, fuel and the raw material of tatami, binderless board, concrete[23], bioethanol[24] and solid fuel[20]. Since most of the food wastes happen in Shizuoka can be the raw material of animal feed, fertilizer, medium, binderless board, bioethanol and solid.

In the first, we were thinking to use rice straw to make mushroom. But the biggest problem we face is the output. We were trying to clarify the possibility by calculate the benefit of making mushroom by rice straw. According to the data form Kanto Regional Agricultural Administration Office and Ministry of Agriculture, Forestry and Fisheries Agricultural Production Bureau, we can figure out rice straw production of Shizuoka Prefecture will be 90,000 tons per year by calculation. And the experimental results show rice straw 45g can make 29.5 g mushrooms by 2 months. If we assume that collection & production losses are 30% and use all rice straw in Shizuoka to make mushroom. Then we can get 41,000 tons mushroom. And the market price of mushroom in 2012 summer was 207JPY/Kg, so our amount of sales will be 8,487 million JPY. It sound great in the beginning, but Japan's total demand of mushroom is only around 11,000 tons. Only use Shizuoka's rice straw will be over the total demand, so obviously this cannot be the only output.

Since this reason, we try to build a model which has more diversity. But another problem we face is the unbalance between collection revenue and collection cost. Usually, waste disposal companies have earnings in two parts, collection the wastes and sell the final products. In collection part, the waste generators usually cannot disposal the waste by themselves. Since that waste generators need to pay the disposal fee to waste disposal companies, and that is extremely important for the profitability of the waste disposal company. But back to the rice straw case, those noon reuse rice straw were burned in farmland. Burning rice straw won't cost much, and also can work as fertilizer. So basically the waste disposal company is hard to get collection revenue from farmer. Even some of areas in Japan start to ban burning rice straw in farmland, expectable revenue still low. And also because rice straw's volume is huge, the collection cost will be very height. According those reasons, we decide not to put rice straw in to the model.

9.3 Tea Waste

Japan is a country where the population consumes a large quantity of tea. Tea beverage is really popular among Japanese people. Shizuoka is a place with the most of tea manufacturing company. Therefore, the produce of tea waste is in great number. However, Japan has been working on recycling tea waste for a long period. Now, there are many different ways of reusage of tea waste that have been developed.

Based on Ito En Company, the recycling of tea waste been increased to 99%. This means that nearly all tea waste has been reused without wasting. Actually, Ito En is a leading company in tea waste recycling. ITO EN has developed a wide array of methods for recycling used tea leaves and incorporating recycled tea leaves into a range of products and materials. These include "Chahaigo Board," which is used in tatami mats type of traditional Japanese flooring found in Japanese-style rooms and "Chahaigo Resin," which has been used as a material for manufacturing vending machines and park benches. We have also been involved in the development of plasterboard containing used tea leaves and have developed paper and cardboard made using hydrated tea leaves. Not only does recycling conserve resources but the antibacterial and deodorizing properties of catechins retained in the tea leaves can be utilized in products made from recycled tea leaves, thereby adding greater value.

Besides, tea waste can also be used as a heavy medal absorbent as well as animal feeds. With proper processing, tea waste can be manufactured to become a nutritious foods for animals.

Nowadays, based on the idea of tea mats, paper made from tea is also developed. Tea candle and tea matches are also new inventions of the recycle of tea waste.

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